Before the

Federal Communications Commission

Washington, DC 20554

In the Matter of Revision of Part 15 of the FCC's Rules Regarding Ultra-wideband Transmission Systems	ET Docket 98-153

Ex Parte Comments of Time Domain Corporation
In Response to Qualcomm Filing of January 11, 2002

7057 Old Madison Pike
Huntsville, AL 35806

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Executive Summary

The Qualcomm Ex Parte submission of January 11, 2002, adds little, if anything, that has not already been entered into the record. The report contained in the Qualcomm submission essentially states the following: When a GPS receiver, with augmentation, is operated at the very edge of its detector performance capability, any slight increases in noise from any source or slight loss of desired signal will have a substantial impact on its performance. Qualcomm has validated standard radio theory. However, errors in their application of the theory will drastically alter the conclusions they derived from their testing.

Following are several notable points about this most recent Qualcomm submission:

1) Several critical factors concerning their measurement techniques, performance criteria, and influence of noise sources attendant to their test arrangement were not addressed. For example, what system or technique was used to determine the C/No[1] of 34 dB-Hz? What influence does the noise inherent in their test set up have on their reference C/No and, consequently, on the results?

2) The report does not contain many points of critical information to help one assess the realistic impact of UWB emissions in the GPS L1 band on the performance of their gpsOne system since the testing was not conducted in an operational environment. Their testing was done in a sterile environment within a shielded enclosure. Data from publicly available sources suggests that Qualcomm's instant testing does not reflect any real-world environment where there would be numerous effects from multi-path and, if nothing else, the human who would be holding the cell phone in order to push the 9-1-1 numbers to call for assistance. Establishment of a viable cell phone link is a requirement to evaluate E911 performance.

[1] C/No refers carrier to noise ratio.

3) According to Qualcomm’s submission, there appears to be little difference between noise-coded and non-noise-coded signals. This is very indicative of a GPS system that is operating at its maximum sensitivity threshold where the ability to separate performance degradation due to UWB noise from performance degradation due to its own system noise and other extraneous noise is impossible.

4) Qualcomm's interference distance analysis is based on two erroneous assumptions; a) an inverse linear extrapolation rate and b) a proposed Part 15 power level of -41.3 dBm. When correcting their data according to the proposed Part 15 specification, the results of the Qualcomm analysis are markedly different. Distances of tens of meters become distances of less than 2 meters!

5) In view of the assumptions made by Qualcomm in designing and implementing their test set up, the results of the data taken with continual interference from a UWB source during this testing cannot be rationally extrapolated to conditions of actual usage and the system’s ability to meet the FCC mandated E911 requirement.

Qualcomm has cloaked their concern surrounding any potential interference to GPS from UWB in the mantle of "UWB will endanger safety-of-life-applications" without any scientific basis just as other opponents of UWB have done.

Augmented GPS Receivers (gpsONE)

On January 11, 2002, Qualcomm filed an Ex Parte Presentation in ET Docket 98-153. In that report Qualcomm filed the results of laboratory environment testing purporting to show the degradation effects that any UWB signal would have on the position readout accuracy of their augmented GPS receiver as it is incorporated within a hand held cellular telephone (gpsONE). To understand why those results are nothing more that a laboratory experiment, one needs some understanding of the Qualcomm gpsONE receiver.

GpsONE uses a proprietary technology developed by SnapTrack Inc. to provide location services to meet the various needs of the particular subscriber. In the case of cellular service providers, the technology is touted as a way of meeting the FCC mandated North American E911 performance requirements. Augmented GPS receivers in this application receive a set of key aiding data from the local cellular server that enables them to decode successfully GPS signals that would otherwise be below the system noise level of the handset GPS receiver. Without this key data from a local cell server, augmented GPS receivers such as the gpsONE are unable to provide any location information. Thus, one of the main limiting factors in use of this technology for E911 positioning information will be the ability for the handset to establish a two-way link to the associated cell site base transmitter where the cell server is located.

C/No Noise Characterization

Qualcomm stated that they performed extensive measurements within various buildings and inside vehicles and determined that the C/No in these situations was "around" 34 dB-Hz 95% of the time for building locations. For in-vehicle locations they state the C/No was less than 34 dB-Hz 82% of the time. They provided no information on what GPS receiver systems were used to measure this figure, the number of satellites observed, whether the 34 dB-Hz number represents an average across all received satellites, whether it represents the satellite producing the maximum or minimum C/No in the GPS receiver, the acquisition times involved in collecting the data, or any information about the actual placement of the receivers within the "buildings" and "in-vehicle" locations. They also omitted statements regarding how the data is representative of the gpsONE phone if a gpsONE phone was not used and the ability of a cell phone to establish a call at the measurement locations, a principle requirement for determining compliance with the E911 location services requirements.[2] In short, the 34 dB-Hz represent a C/No number that may well not be representative of the situations the FCC considers germane to satisfying its E911 requirements.

Their use of the term "around 34 dB-Hz " is quite interesting. Obviously this can only be interpreted to mean there is a delta, or range of data, around the 34 dB-Hz figure of at least a few dB. In looking at their results in Figures 4.2 and 4.3, one can see that a few dB can make a very large difference in the measured position error. Assuming it was Qualcomm's intent to show a significant interference potential from UWB sources, it can be assumed that they would select that portion of the range that would show significant interference levels from UWB to their proprietary system.

It should also be noted that the above C/No characterization pertains only to locations either in a building or in vehicle and that predominately for in-vehicle locations the C/No can be expected to be much lower. This factor is significant since Qualcomm was operating the phones near their maximum sensitivity point. A lower value of C/No would likely result in the inability of positioning information to be retrieved from the phone since the GPS signal level would be below the sensitivity level of the gpsONE. This conclusion is supported in the report that shows 8 meter position errors from the reference phone with no interfering UWB signal as contrasted with a 4 meter positioning error for a scenario where the GPS signal would be expected to be above a value of 34 dB-Hz[3] clearly showing marginal system operation resulting from internal phone system noise and contributory noise from the Qualcomm test set up. It must be noted at this point the contributory noise from the Qualcomm test set up in the "reference" phone path

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[2] FCC bulletin OET 71, " Guidelines for Testing and Verifying the Accuracy of Wireless E911 Location Systems".

is considerably less than the contributory noise in the "test" phone path. Qualcomm did not address this differential in path noise. When operating a receiver at extremely low desired signal levels and purporting to measure UWB interference levels in the "test" phone, these sources of noise cannot be ignored because they become a significant portion of the interfering signal that is being measured.

With lower GPS signal levels the system would be more sensitive to UWB interference, however, the gpsONE receiver in the Qualcomm test set up was essentially operating at its maximum sensitivity point. In this situation, the gpsONE receiver would likely cease to function at all with a lower desired signal level. Further, with lower signal levels using Qualcomm's experimental set up, the impact of the noise sources in the UWB signal path would increase rapidly.

Laboratory Results versus Real World Testing

The GPS signal used in the testing allegedly relates to the signals that would be found in typical operating environments. It is clear, however, that this data is not at all representative of what would be found in and around buildings where multipath would be a prominent factor. The data from the Qualcomm submission of January 11th, Figure 1 should be compared to the data extracted from a technical paper, Figure 2, describing the performance of the SnapTrack system that was presented at an Institute of Navigation conference[4] (the "ION paper"). In the case of the Qualcomm submission, the test setup allowed the gpsOne "reference" phone to track an average of 9.0 satellites, with the minimum number of tracked satellites being 8 and a standard deviation of about 0.6. In the case of the data from the field measurements described in the ION paper, the best non-open field measurement was in a narrow street with 2 to 10 story buildings on either side. In this middle-of-the-street case, the maximum number of satellites tracked was 8 with 9 available, and the average was 5.7 with a standard deviation of 1.1. Clearly, the

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[3] M. Moeglein and N. Krasner, "An Introduction to SnapTrack Server-Aided GPS Technology," the Institute of Navigation's Conference in 1999. Available from: www.snaptrack.com/AtWork/ion.pdf.

laboratory does not represent the real world – especially an in-building world – and the results of these tests cannot be extrapolated to typical operating environments.

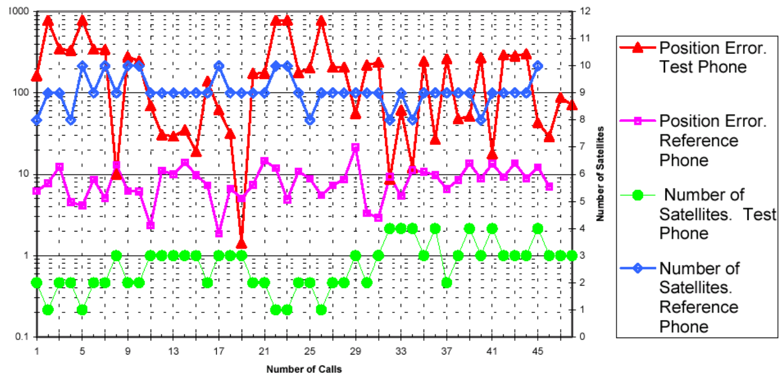

Figure 1. The number of satellites tracked by the Qualcomm reference phone as shown in the Qualcomm submission. In this measurement the reference receiver tracked a minimum of 8 satellites and was able to track an average of 9.0 satellites.

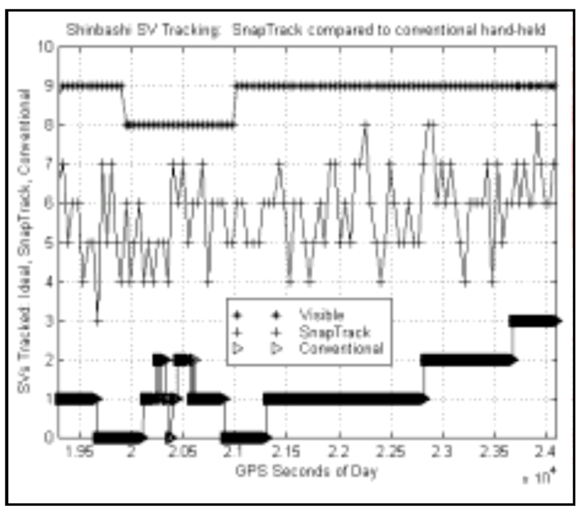

Figure 2. A graphic showing data taken in a narrow street with 2 story buildings on either side. The upper track on this graph represents the performance of the SnapTrack system. The data shows that the SnapTrack system was able to track at most 8 satellites and averaged 5.7 satellites over the duration of this measurement.

The ION paper lists a number of test sites. The data shown is identified as the "urban street" environment for which the system had a 68.3% accuracy of 15 meters. Most of

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[4] Id.

the locations have position accuracies worse than that shown for this site. The comparison clearly shows that the UWB evaluation conducted by Qualcomm did not use GPS signals representative of what would be found in any real-world operational environment.

Table 1. Data table from ION paper showing SnapTrack performance in several environments.[5]

Environment	Conditions	Yield	68.3 % Horizontal Error, m
Outdoors	Open Site	100%	4
Urban Street, Shinbashi, Tokyo	2 – 10 story building buildings, narrow streets and alleys	100%	15
Inside Sport Utility Vehicle	Parking lot surrounded by redwood trees and two-story buildings. Antenna placed on inside shoulder	100%	17
Two story house	Center of basement	100%	20
Two-story office building	1st floor, interior room	94%	22
Urban canyon, Denver, CO	20 – 30 story buildings, wide streets, altitude aided	98%	29
50-story building	Glass/steel building, 21st floor, 14 ft. from outside wall	89%	84

Testing at the Unreliable Edge of Performance

The Qualcomm report does indeed document that when their gpsOne system is operated at the very edge of performance, as was done in their test set up, slight changes in C/No cause dramatic changes in the accuracy of the system. Figures 4-2 and 4-3 in the Qualcomm submission show that a 1 to 2 dB decrease in C/No causes the accuracy to degrade by a factor of approximately ten. Further, using the error distances in the above

[5] Table 1, SnapTrack ION paper.

table from the ION report and crossing those error distances over to the Lab testing shown in Figures 4.2 and 4.3 from the recent Qualcomm test report, one can determine what equivalent noise background level is required to produce a position error equal to the positioning error resulting from the Qualcomm laboratory testing. From these figures, that equivalent noise level is approximately -97 dBm. In other words, ambient noise in the vicinity of the gpsONE cell phone of the order of -97 dBm would generate positioning errors at the above locations equivalent to the laboratory testing. Of course there is no way to determine if the above positioning errors in the ION report were the result of ambient noise, low GPS signal levels and associated multipath, or noise and timing errors in the measurement system. This clearly indicates again that laboratory measurements of the type performed by Qualcomm are not suitable to use in drawing performance conclusions related to UWB interference in real-world applications.

Qualcomm Test Setup

Qualcomm's test arrangement consisted of capturing a live sky GPS constellation from a rooftop antenna, amplifying the output, feeding it down to the test lab, dividing the signal with a splitter and then coupling each signal path to a cell phone through an additional series of splitters and attenuators. Typical antenna gain of an omnidirectional GPS antenna would be of the order of 0 dBi. Thus, the output level from the GPS antenna would be a nominal -130 dBm based on references in the literature.[6] Qualcomm measured the conducted RF path gain from the output of the GPS antenna feed to the antenna input for both phones and reported the value to be -15.4 dB. Thus, the actual GPS input signal to each phone was -130 dBm + (-15.4 dB) or - 145.4 dBm or just 4.6 dBm above the specified maximum sensitivity (-150 dBm) of the gpsONE handsets! From Figure 3.2 of the Qualcomm report it can be seen that numerous splitters, isolators, and attenuators were in the path of each receiver. Each of these components introduces noise into the system that increases the measured receiver degradation thus skewing the test results. Also, the output of the UWB source was coupled through various devices

[6] JHU-APL report, Table 1, page 22

with each adding additional noise to the level measured at the handset receiver. Thus, the interference levels measured using the Qualcomm test set up would be a combination of UWB noise power plus noise power from devices in the RF path between the UWB source and the "test" hand set. Noise power from circuitry that follows the attenuator used to reduce the signal from the UWB source would essentially be additive noise power from the UWB source. This is a critical factor that must be remembered when reviewing the results of the Qualcomm test report because that report did not adjust its data to reflect this oversight.

Position Error Calculations

In Figures 4.2 and 4.3 Qualcomm presents position error as a function of UWB power for non-dithered and dithered UWB signals. The plots are based on a UWB power level of -41.3 dBm, however, the FCC did not propose power levels to be the performance specification; rather, compliance was proposed to be on the basis of field strength measured at 3 meters. The FCC also proposed to protect the GPS service by requiring UWB signals to be 12 dB below the general limit or equivalent to 125 uV/m measured at 3 meters in the GPS band. When measured on an open field site at a frequency of 1575 MHz, a UWB device compliant with 125 μV/m limit will have a power level of -59.3 dBm. Inserting this power level into the free space path loss model used by Qualcomm, the separation distance required to meet the performance criteria specified in Figures 4.6 through 4.9 of their report is actually 1.8 meters or approximately 5 feet! This number is also in close agreement with conclusions reached by the John Hopkins University Applied Physics Lab (JHU-APL) report that is part of the record in the proceeding. That report, although based on a UWB source with a power level of -47.3 dBm, concluded that UWB posed no significant threat of interference to GPS systems at distances of 3 meters or more with gradually increasing interference effects occurring at distances less than 3 meters. One additional point should be noted, the 1.8 meter distance is based on results produced by the Qualcomm test set up and is subject to further reduction as a result of uncorrected noise errors contained in their report. A comparison of corrected and uncorrected results can be seen in Figure 3 and Figure 4 below.

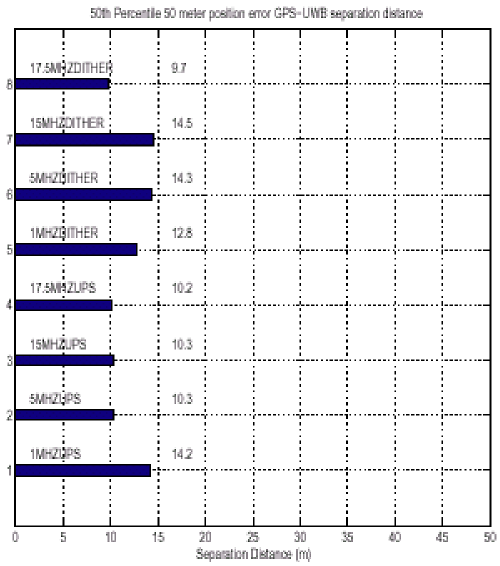

Figure 3. UWB – GPS separation distance for 50 m error 50% of times from Qualcomm report.

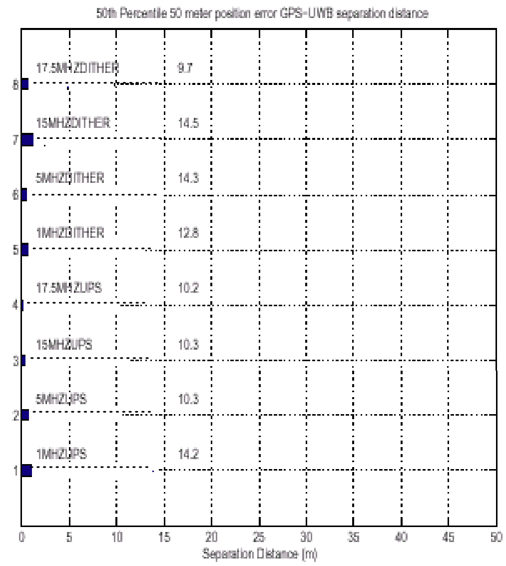

Figure 4. UWB – GPS separation distance for 50 m error 50% of time AFTER correcting for Qualcomm errors

Another error made by Qualcomm in their reduction of the data to calculate interference distances was the use of a free space extrapolation formula. Free space path loss is only applicable when there are no intervening objects between or in close proximity to the path between the radiation source and the receiver antenna. Use of a free space path loss formula for the investigated "in building" and "automobile" situations their report is based on would arguably be valid for distances of 3 to 5 meters for in building scenarios and much less for the automobile scenario. Beyond 3 to 5 meters, there would typically be wall attenuation and scattering of the signal from objects in the general location of a handset with the situation worse for an automobile scenario. Thus, it is inappropriate to base distances and conclusions on the use of such a formula at the distances specified in the Qualcomm report.

Summary

The flaws in the Qualcomm submission are substantial. The report does not support its conclusions. By far the best analysis of the interaction of GPS and UWB remains the Johns Hopkins University Applied Physics Laboratory submission to the record. Qualcomm's concerns about UWB are not warranted, especially when one considers the

NPRM proposal to limit emissions below 2 GHz, the natural roll-off of UWB emission below 2 GHz, and the environment in which UWB is likely to be used.

The FCC's NPRM proposal is, therefore, adequate to protect the GPS band.

Respectfully,

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s/Paul Withington
Vice-President
Time Domain Corporation
Cummings Research Park
7057 Old Madison Pike
Huntsville, AL 35806
Paul.Withington@timedomain.com

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Cc (via email): Bruce Franca, Julius Knapp, John Reed, Peter Tenhula, Bryan Tramont, Paul Margie, Monica Desai